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for Irrigation in Humid Regions

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BRACKISH WATER FOR IRRIGATION IN HUMID REGIONS [1]

Jesse Lunin and M. H. Gallatin [2]

INTRODUCTION

Moisture is necessary for plant growth. Rainfall in humid areas does not always supply crops with adequate moisture throughout the growing season. For this reason, during the past several years in the Eastern States there has been a marked increase in the use of irrigation to supplement the rainfall.

Benefits derived from irrigation are numerous. Frequently when a drought occurs during a critical period of crop growth partial loss of the crop may result. Sometimes total loss is the result. Irrigation would enable a farmer to save his crop and possibly to let him take advantage of a resultant higher price. Irrigation may mature crops sooner and hence bring a more favorable market price. Very often the quality of crops can be improved by irrigation during a period of limited rainfall. In areas where pastures are irrigated during late summer and fall the grazing capacity has been greatly increased. Furthermore, there is an abundance of data in the literature to indicate that there is a greater response to many cultural practices such as fertilization when irrigation is used to ensure adequate soil moisture. Improved irrigation equipment and better information on water requirements of crops have greatly encouraged this trend.

One of the primary requisites for irrigation is an adequate source of water. There are many areas along the Eastern Seaboard States where farmers have found their only adequate supply of water to be subject to saline contamination. The question thus arises as to what extent this brackish water can be used for irrigation.

SOURCES OF BRACKISH WATER CONTAMINATION

In this discussion brackishness will refer to the salinity in water arising from contamination by sea water; it therefore will have, for the most part, the same relative composition. Actual analyses of brackish waters have shown this to be true. Sea water contains several salts.

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[1] Work conducted in cooperation with the Virginia Truck Experiment Station, Norfolk, Va.

[2] Soil Scientists, Eastern Soil and Water Management Research Branch, Soil and Water Conservation Research Division, A.R.S., at Norfolk, Va.

The major salt is sodium chloride, ordinary table salt; it makes up approximately 78 percent of the total salts present. Other salts present are magnesium chloride (17 percent), calcium sulfate (gypsum) (3 percent), and sulfate of potash (2 percent). These percentages may vary somewhat and some other salts may be found in very small amounts.

Brackish contamination can be found in many sources of irrigation water. In many areas along the Eastern coast, tidal inlets adjacent to tidal marshes are being dammed to form seepage ponds. These ponds are brackish initially, but if pumped almost dry and allowed to fill from fresh-water runoff and seepage, the salinity will usually drop to a relatively low level within a year or two. These ponds can become recontaminated by overtopping of the dam during a hurricane or northeaster storm or by overpumping, which will result in seepage of salt water from the adjacent marsh. Limitations as to the irrigable acreage from a given pond must be recognized so as not to overreach the capacity of the pond. In planning these ponds, careful consideration must be given to the construction of the dam and spillway to prevent overtopping by taking into account past history of storm tide levels.

Another source of brackish water is created by diking an area adjacent to a tidal marsh. Very often this ditch serves as an outlet for drainage ditches from the adjacent cultivated areas. The ditch behind the dike will gradually fill with fresh water seepage and runoff. These structures usually contain a gate to allow removal of excess water in wet seasons and, at the same time, prevent tidal water from coming in during high tide. This source of water is usually brackish initially, owing to residual salt accumulation, and may be recontaminated by salt water seepage from the tidal marsh in dry years or by overpumping.

In many coastal areas wells have become brackish as a result of salt water intrusions caused by the encroachment of sea water in the underground strata. This has resulted in many instances from the greatly increased use of water in expanding urban and industrial areas along the coast. Frequently well water may not be brackish at the outset of pumping but will become so as pumping progresses. To avoid this danger of overpumping wells during irrigation, the farmer will irrigate from storage ponds which he can gradually fill from his wells. Or in instances where pumping capacities for irrigating directly from wells are inadequate, he can pump water into storage ponds to accumulate an adequate volume for irrigation.

Many natural bodies of water along coastal areas are not too brackish for irrigation use. The upper portions of some streams may still be influenced by tidal fluctuations and therefore brackish; nevertheless they may be used for irrigation. The use of automatic tidal gates on smaller streams tends to keep out sea water at high tide. Another alternative is to pump at low tide when the degree of brackishness is at a minimum. Certain bays and sounds near the coast are not too brackish to serve as a source of irrigation water. These sources should be carefully checked periodically for salinity because the degree of brackishness may change so as to render the water unsuitable for irrigation.

FACTORS AFFECTING SALT ACCUMULATION

The predominant type of irrigation used in the Eastern States is the overhead sprinkler type. This method is now used in over 90 percent of the area under irrigation. Owing to the general shortage of water available for irrigation, applications of 1 to 1½ acre-inches of water are most common. Usually the moisture content of the soil at the time of irrigation is sufficiently low that this 1 acre-inch of water does not penetrate beyond a 6- to 9- inch depth in the soil. Hence, salts contained in the irrigation water are confined to the surface foot of soil. Downward movement of salt by diffusion is negligible. Assuming no intervening rainfall, the application of a second irrigation will increase the salt content of the surface foot still further. Loss of water by evaporation tends to bring these salts to the surface where they accumulate. Salt itself can be removed from the soil only by plant utilization or leaching. Since the amount removed by plant utilization is very small, leaching by rainfall is the primary means of salt removal where the amount of irrigation water is limited. As the moisture content of the surface soil decreases, the salt concentration of the soil solution increases even though the total salt content does not change appreciably.

Intervening rain consisting of light showers does little more than wet the surface soil and has little or no effect on leaching out the salts from the surface. Assuming no heavy rains occur, salts will accumulate in the soil according to the number of consecutive irrigations applied and the salt concentration of the water used. Heavy rains may occur, however, during a crop season. When the rainfall is of sufficient magnitude to cause a downward movement of water below the surface foot, salts will also leach downward to be redistributed in the soil profile. Good internal drainage is of vital importance to leaching. The presence of a plowsole or other type of impedence to drainage will prevent the leaching of salts from the root zone.

Winter rains are an important factor in leaching out salts accumulated as a result of brackish water irrigation. With good internal drainage and at least average rainfall, preliminary experimental evidence indicates that most of the salt accumulated during the crop season will leach out of the soil profile during the winter.

In some areas where an abundant supply of water, though brackish, is available, it is desirable to use applications of 2 or possibly 3 acre-inches of water per irrigation. This practice will allow deeper distribution of salt in the profile, thereby minimizing in the surface soil a resulting salt accumulation from frequent small irrigations. This also reduces evaporative losses. Soils must be deep and drainage good to permit larger applications of water.

Soils are affected by brackish water only by the degree to which sodium is adsorbed from the water by the soil. Large accumulations of adsorbed sodium tend to disperse fine-textured soils making them more plastic and thereby reduce the permeability of these soils to air and water. Free salts, when present in the soil, tend to increase the permeability of these soils to air and water. Hence, when the excess salt has been leached out of these soils by rainfall, the remaining adsorbed sodium may impair the permeability of that soil and result in a poor physical structure.

SALINITY AND PLANT GROWTH

Soils of the humid Eastern States do not normally contain any appreciable quantities of free salts; they are nonsaline. The use of brackish water for irrigation, however, can create a saline condition through an accumulation of salts in the soil. High levels of salt in the soil can be damaging to plant growth.

One damaging effect of high salt concentrations in the soil is to render the water less available for plant use. Under normal soil conditions all but a small part of the water present is available for plant growth. Soil water, frequently referred to as the soil solution, contains dissolved plant nutrients which are available for plant growth, but the salt concentration in nonsaline soils is relatively low. High rates of fertilizer application greatly increases the salt concentration of the soil solution in localized areas. Irrigation with brackish water, depending on its salinity, increases the salt concentration further. As the salt concentration of the soil solution increases, water becomes less and less available for plant use. As the moisture content of the soil decreases through evaporation and transpiration, the salt content of the remaining soil solution becomes more concentrated, thereby rendering the remaining water even less available. Sandy and other coarse-textured soils have a lower amount of available water in comparison to fine-textured soils. The coarser soils dry out more rapidly and will show the effects of soil salinity more readily than the fine-textured soils, which have a greater moisture-holding capacity. This decrease in availability of water restricts plant growth, resulting in stunted crops and poor yields. For this reason soils with high salt content should generally be maintained at a higher moisture level than nonsaline soils.

Aside from the overall effect of concentration of salt in the soil solution, the composition, or specific ions contained in this salt, may adversely affect plant growth. Trees and fruit crops have been shown to be sensitive to high concentrations of chlorides. Toxicity to other ions, such as sodium, bicarbonate, and sulfate, vary with their concentration in the soil solution, and also with the crop grown. The importance of specific ion toxicity with respect to brackish water irrigation has not, as yet, been established. There is also a possibility that the salts added by brackish water irrigation may upset the nutritional balance in the plant, causing a reduction in yield. It has been demonstrated that the sodium and calcium contents of some plants are increased as a result of brackish water irrigation. Adsorbed sodium may exert a secondary effect on plant growth by creating a poor physical structure in the soil as previously mentioned.

In areas where both spring and fall crops are planted, brackish water irrigation of the spring crop may increase salt content of the surface soil to a level where it might affect germination of the fall crop if insufficient rain falls between crops.

In using sprinkler irrigation there is a slight danger of salt burn on the leaves. Usually, the continuous application of water during irrigation keeps the leaves wet and prevents abnormal accumulations of salt. It has been observed, however, that on windy days a fine spray may blow over onto neighboring fields. This spray evaporates rapidly permitting large concentrations of salts to build up on the leaves and a resulting burn. This occurred on a salt tolerant crop (asparagus), which was severely burned along an adjacent field border in this manner.

MEASUREMENT OF SALINITY

In the humid agricultural areas salt rarely accumulates to a great enough extent to give any visible evidence on the surface of the soil. Saline conditions in a field are recognized by a stunted, spotty crop growth. Salt accumulations large enough to cause this may be prevented, however, if the farmer will have both his field and irrigation water analyzed, and indicated measures taken.

One of the first considerations in using brackish water for irrigation is to determine the quality of the water to be used. Where possible, an initial complete chemical analysis of the water in question should be made. This should consist of a determination of the concentrations of all the ions present. For routine checks on water quality a more rapid method is desirable.

Throughout the Eastern States there is considerable variation in the manner in which salinity is reported. For the sake of uniformity, a standard method should be adopted. For these routine analyses, a method suggested by the U. S. Salinity Laboratory at Riverside, Calif., is recommended. This method is based on the electrical conductivity of a solution. Pure water conducts very little electrical current. This electrical conductivity (EC) increases proportionally with increases in salt content. The results are measured in terms of millimhos per centimeter, where 1 millimho equals approximately 640 parts per million of salts. Small simple conductivity bridges are available for conductivity measurements of soil and water samples. For water samples, conductivity measurements indicate the degree of salinity.

As previously mentioned, it is the salt content of the soil solution which is of major importance. This is estimated by filtering the solution from a soil which has been brought to the saturation point by the addition of distilled water. This saturation point is reached when the soil paste glistens and, when the container is tipped, tends to flow. Accumulation of free water on the surface when the soil paste has stood a while indicates an excess of water and should be avoided. The filtered solution is referred to as the saturation extract; it is used to estimate the salinity of the soil solution in the field moisture range.3/ Once this solution is obtained, the salt content can be estimated from electrical conductivity measurements. The amount of water required to be added to the soil to bring about saturation will be small for coarse-textured soils and large for fine-textured soils. The actual amount of water required to reach saturation, expressed as percent of dry weight of soil, is called the saturation percentage (SP).

SALT TOLERANCE OF CROPS

It is not practical to assign a particular salt level at which plants will not grow. Plant growth decreases gradually as soil salinity increases. The rate of decrease and the salinity levels at which comparable reductions in yields occur vary with the crop grown. Within each crop group of Table 1 the salt tolerances of various crops are listed in order of increasing sensitivity of crop. If irrigation water tends toward brackishness, and there is a possibility of salt accumulation in the soil, the selection of one of the more salt-tolerant crops is advisable.

Although soils are usually nonsaline at spring planting, frequent brackish irrigations of a spring crop may result in a salt accumulation in the surface soil at time of planting a fall crop. Should this occur to any great extent, germination of the fall crop may be depressed. Band placement of fertilizer too close to the seed will increase salinity and inhibit germination. In furrow type irrigation, salt tends to accumulate in the ridge, thereby creating a much higher concentration at that point. Seed planted on the ridge may thus be adversely affected. With sprinkler type irrigation this effect is negligible. Salt tolerances, listed above, reflect, with some exceptions, the effect of salt on germination.

3/ The moisture content at saturation is roughly twice that at field capacity and four times that of the wilting percentage.

Table 1.--Salt tolerance of plants 1/

Plants that can tolerate		
Up to 8-16 millimhos 2/	Only up to 4-8 millimhos 2/	No more than 2-4 millimhos 2/
	FIELD CROPS	
Barley, sugar beets, and cotton	Rye, wheat, oats, sorghum, corn, and flax	Field beans
	FORAGE CROPS	
Saltgrass, Bermudagrass, and barley hay	Sweetclover, Dallisgrass, Sudangrass, alfalfa, Tall fescue, wheat and oat hays, Orchardgrass, and vetch	White clover and Ladino clover
	VEGETABLE CROPS	
Garden beets, kale, asparagus, and spinach	Tomatoes, broccoli, cabbage, peppers, cauliflower, lettuce, sweet corn, potatoes, carrots, onions, peas, squash, and cucumbers	Radishes, celery, and greenbeans
	FRUIT CROPS	
	Pomegranate, figs, grapes, cantaloupe	Pears, apples, oranges, plums, apricots, grapefruit, peaches, and lemons

1/ Crop plants listed in order of increasing sensitivity.

2/ These figures represent the electrical conductivity (EC_e) of the soil saturation extract, where 1 millimho equals approximately 640 p.p.m. of salts.

Another factor to consider is the stage of growth of the plant at the time of irrigation. Application of irrigation water with a high salt content to young seedlings will generally result in a greater decrease in yields than if it were applied to more mature plants. The greater part of the root system of a more mature plant is below the zone of greatest salt accumulation and therefore not affected by it. The root system of a young plant is concentrated in the surface soil and therefore more subject to the effects of the applied salt.

The above table of salt tolerance of crops is general and subject to variations due to location and climatic conditions. This latter factor is of significance where both a spring and a fall crop are grown. It has been demonstrated that plants are less susceptible to salt injury under cool humid conditions than in a hot dry climate. It is therefore probable that salt damage will be less for a fall-sown crop than for a spring- or summer- sown crop, assuming the same degree of salt accumulation at time of spring or summer planting and at time of fall planting.

ESTIMATION OF SALT ACCUMULATION

As previously indicated, the resulting salinity of the soil solution rather than the salinity of the irrigation water determines the effect on crops. For the purpose of making recommendations, it would be desirable to be able to predict how water of a given salt concentration will affect the salt content of the soil solution.

The following simplified equation should enable the field worker to predict what degree of soil salinity to expect from a given number of irrigations of brackish water if he knows the electrical conductivity of the water to be applied and that of the saturation extract (see below) of the soil prior to irrigation.

$$EC_{e(f)} = EC_{e(i)} + \frac{n(EC_{iw})}{2}$$

Where $EC_{e(f)}$ = electrical conductivity of saturation extract after irrigation is completed.

$EC_{e(i)}$ = electrical conductivity of saturation extract prior to irrigation.

EC_{iw} = electrical conductivity of irrigation water.

n = number of irrigations.

This equation is based on the assumption that no intervening rainfall capable of leaching salts has occurred. If no previous saline water has been applied and the soil is known to be nonsaline initially, the equation can be further simplified by assuming a value of 0.5 millimho for $EC_{e(i)}$.

For example, a farmer who has irrigated his spring crop with brackish water wants to irrigate his fall crop of beans with water having an electrical conductivity (EC_{iw}) of 4 millimhos. A saturation extract of the soil from the area indicates a residual salinity of 1.5 millimhos ($EC_{e(i)}$). Thus $EC_{e(f)} = 1.5 + \frac{(1)(4)}{2} = 3.5$ millimhos. Since beans are not recommended for soils having EC_e values over 4 millimhos (see table 1), this farmer should not apply more than one irrigation of this saline water to his crop.

SAMPLING PROCEDURES

Correct procedures for sampling soil and irrigation water are essential to a satisfactory evaluation of a salinity problem. A soil sample must be representative of the area in question. Samples must also be accompanied by sufficient information to enable proper interpretation by a technician. The Soil Sampling Data sheet and Water Sampling Data sheet at end of this publication illustrate the type of information required.

Sampling of wells should be done both at onset of pumping and toward the end of the pumping cycle. It is possible for the water to become more brackish after a heavy pumping cycle. If this tends to happen, additional samples may be taken during the course of future irrigations to keep track of changes in salinity. Seepage ponds subject to brackish water contamination should be sampled prior to irrigation. Samples should be taken from the pump location at two depths: 1 foot and 4 feet--or as close to the bottom as possible. For a more complete salinity check on a pond, samples also should be taken at these two depths at the dam and at the upper end. Streams, or other bodies of water subject to tidal variations, should be sampled at the pump location at various tidal stages to determine the range of brackishness. This should indicate whether the source of water may be used at any time or only during a specific tidal stage.

Clean, wide-mouthed bottles with at least a 4-oz. capacity should be used. For deep samplings in ponds and streams, the end of a bamboo fishing pole may be fitted with a loop of plumber's strap for holding the sample bottle. By fitting the bottle with a rubber stopper that has a string attached, one can take deep samples by submerging the stoppered bottle at the end of the pole to the desired depth and then removing the stopper by pulling the string.

Soil samples of the surface 6 inches are taken with a sampling tube or spade from several locations within the area and composited. After the soil is thoroughly mixed, a subsample of not less than 1 pound should be taken for analysis. In taking the samples, avoid bands of fertilizer, because fertilizer will tend to give a false picture of the overall soil salinity. Samples from the 6-to 12-inch depth should be taken at the same time in a similar manner.

Soil Sampling Data

Sampled by ____________________ Mail Address ________________ Date _____

State ________________________ County ______________________________

Site Location ____

Owner's Name _______________________ Soil Conservation District __________

Direction for locating site, (Use reverse side for sketch of roads, showing the nearest settlement, and location of sampling points from local land marks).

Profile description; including such factors as, soil series, hard pan, water table, infiltration rate, etc.

Topography ____________________ Slope ____________ Degree of erosion _____

Microrelief of sampling site, furrow ridge, etc.

Sample Depth ___________ Composite Sample Depth ________________________

No. of holes, Sampling pattern _____________ Farming History ______________

Years of Cultivation _____________________

Years of Irrigation _____________________ Source of Water ______________

Crop Data:

Rotation:

Yield History:

Detailed description of plant condition at time of sampling:

Management Practices:

Water Sampling Data

Sampled by____________________Mail Address________________________Date__________

State____________________County___________________Nearest Town__________________

Location of Well or Pond____

Owner's Name_____________________________Soil Conservation District_____________

Direction for locating well or farm (Sketch map may be drawn on reverse side giving distance and local land marks for location).

Well:

Depth________________________________Yield in G.P.M._________________________

Time of Sampling______________________

Start Pumping_________________________End Pumping_____________________________

Use; direct___________________________Recharge for Pond______________________

Pond:

Size of Pond: Width___________Length___________Depth___________Capacity_______

Source of recharge____________________

Stream_____________________Ground Water_____________________Well______________

Location of Pond____

Type of Pond. Burrow pit.________________________

Dammed stream_________________________Dammed Tidal Inlet______________________

Crop Data, on Field Water is Applied:

Rotation:

Yield History:

Detailed description of plant condition at the time of sampling:

Management Practices: